

# **ELECTRONIC FUNDAMENTALS**

## **SERVICE PRACTICES 38**

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# Service Practices 38

## INTRODUCTION

You have studied the basic principles of FM and FM receivers. From this lesson you will learn how these principles are applied to practical receivers. You will learn about the *front end*, the audio stages of FM receivers, and automatic frequency control of the r-f oscillator. You will also learn about a kind of distortion of the signal from a single FM broadcast station called *multipath distortion*. Finally, you will learn the procedures for servicing FM receivers.

### 38-1. THE FM FRONT END

The first three stages in an FM receiver are grouped together and called the front end or tuner section of the receiver. These stages are the r-f amplifier, the mixer, and the oscillator. The functions of the three stages in the front end are similar to the functions of corresponding stages in the AM receiver. The r-f amplifier amplifies the incoming r-f signal. The amplified r-f signal combines with the oscillator signal in the mixer to form the intermediate-frequency signal.

**The R-F Amplifier.** The r-f amplifier performs three important functions in the FM receiver. It improves the signal-to-noise ratio, and makes the receiver more sensitive and more selective.

Without an r-f amplifier, the first stage of the receiver would be the mixer or converter. Considerably more noise is generated in a mixer or converter than in an r-f amplifier stage. The noise developed in the first receiver stage largely determines the receiver signal-to-noise ratio. It is desirable to have as little noise as possible in this stage, so the r-f amplifier is used.

Although the increase in gain produced by the use of an r-f amplifier stage is relatively small, sensitivity is increased, since the noise generated in the r-f stage can be overcome by a weaker signal and therefore the receiver is sensitive to weaker signals. The gain obtainable from an r-f stage at the high frequencies of the FM band is low. But the increase is useful.

The gain of an r-f stage (output signal divided by the input signal) is in many cases about 10. A gain of as high as 15 – or even higher – may be found in some cases. In older FM receivers using r-f amplifier tubes with low transconductances, an r-f gain as low as 3 may be normal. Use of an r-f amplifier permits the gain of the i-f amplifier to be reduced in proportion to the gain of the r-f amplifier. Thus, the possibility of regeneration and oscillation in the i-f stages is minimized. A tuned r-f amplifier adds additional selectivity to the receiver. The amplifier rejects image signals and other unwanted signals not rejected by i-f tuned circuits.

Most FM r-f stages are tuned. However sometimes an untuned r-f stage is used. This stage is broadly tuned to the entire FM band, rather than to individual channels. Such a stage is cheaper to make than a tuned r-f amplifier, but its selectivity is not as good. The untuned r-f stage relies upon the selectivity provided by the mixer grid tuned circuit to reject undesired signals within the FM band.

Pentode tubes are often used as r-f amplifiers. Conventionally connected triodes are not suitable; their large plate-to-grid capacitance permits an excessive amount of signal to be fed back from plate to grid, thereby promoting oscillation. In a pentode tube, the plate-to-grid capacitance is very small, minimizing or eliminating this possibility.

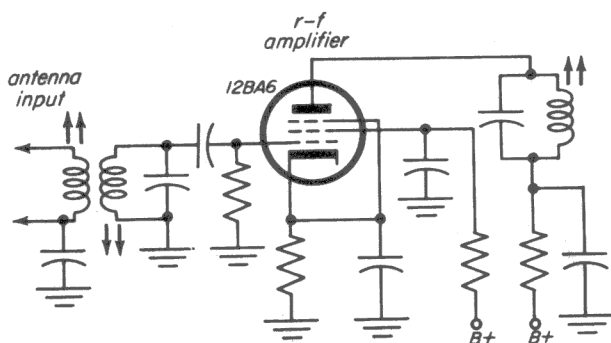


Fig. 38-1

The bandpass of the r-f amplifier should be approximately 200 kc. Generally, it is much larger than this, because the tuned-circuit  $Q$  necessary to obtain a bandpass limited to 200 kc, at frequencies in the vicinity of 100 mc, is too high to be achieved in practical circuits. But even though the bandpass is generally larger than 200 kc and the selectivity is less than optimum, selectivity is nevertheless adequate to reject the interfering signals encountered in normal installations.

A schematic of a typical r-f amplifier circuit is shown in Fig. 38-1. Note that it looks practically the same as similar r-f amplifier circuits used in AM receivers. The major differences result from the large inductive reactance of small lengths of wire at FM broadcast frequencies. FM coils have considerably fewer turns than AM r-f coils and component layout, lead dress, length of wires, and location of grounds is more critical. The inductive reactance of one inch of No. 22 AWG wire at a frequency of 1,000 kc, which is near the center of the AM broadcast band, is less than two-tenths of an ohm — a negligible value. At a frequency of 100 mc, which is near the center of the FM band, the inductive reactance of the same piece of wire is 16 ohms. When the inductive reactance of wiring becomes as great as it is at FM frequencies, the wires function like coils. They may introduce feedback as well as other troubles. Therefore, wires are kept as short as possible. Wiring is carefully laid out in order to eliminate the possibility of undesired coupling between the input and output of a stage. Circuit components are laid out with similar care.

Also, stray capacitance is troublesome in an FM r-f stage. While stray capacitances are small, the capacitive reactance they introduce is much lower at FM-band frequencies than it would be at broadcast-band frequencies. When there is a relatively low capacitive reactance between the plate and the grid of an r-f amplifier tube, an appreciable amount of signal current will be fed back from plate to grid. This feedback may reduce the stage gain, or it may promote oscillation, depending on the phase relation of the input and feedback signals. Stray capacitance can introduce other troubles as well. Stray capacitance is minimized by careful wiring layout, use of minimum lengths of wire, and proper choice and placement of components. Interelectrode capacitances, or the capacitances between tube electrodes, must be kept small. The use of miniature tubes, which contain electrodes of small area, provides the required low values of interelectrode capacitance.

**The Oscillator.** One of the most important requirements of the FM oscillator is that it have suitable stability. If much oscillator drift occurs, the FM receiver cannot do an adequate job of rejecting noise; also distortion takes place. Let's consider why this is so.

Oscillator drift causes the i-f carrier to arrive at some point other than the center of the i-f and detector response curves. As a result, the difference in amplitude between i-f signal frequencies that produce maximum output in the tuned circuits and i-f signal frequencies that produce minimum output increases (Fig. 38-2). Therefore, the incoming FM signals have a greater amount of amplitude variation and phase shift. The effects of amplitude variations due to noise are added to the amplitude variations due to tuned circuit action. The total amplitude variations may swing the FM signals beyond the range within which adequate limiter action takes place, causing noise to become audible. The increased phase shift produces undesired frequency deviations that result in audio distortion. The audio signal will be reproduced along a nonlinear portion of the S curve, causing it to be distorted.

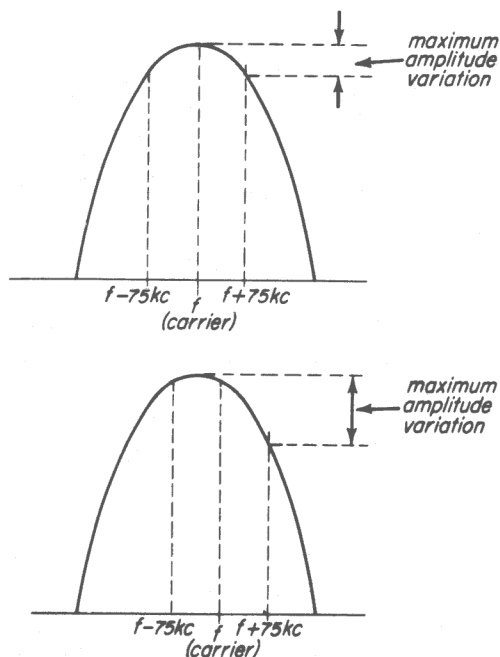


Fig. 38-2

A certain amount of oscillator drift is unavoidable. Heat causes oscillator tank circuit components to expand, changing the frequency at which they resonate. Interelectrode capacitances in the oscillator tube change as the tube is heating up. A change in the grid-to-cathode interelectrode capacitance is in parallel with the oscillator tuned grid circuit (Fig. 38-3) will change the frequency at which the oscillator operates.

When the bandpass of the i-f and detector stages is 200 kc wide, oscillator drift of 25 kc is permissible, since such drift is not great enough to shift the i-f signals outside the bandpass (Fig. 38-4). But the oscillator tends to drift more than 25 kc. Certain chassis layout and design features are used to restrict the drift to permissible limits. Sources of heat are kept away from the

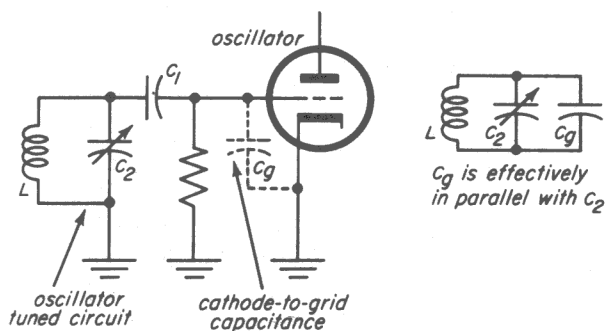


Fig. 38-3

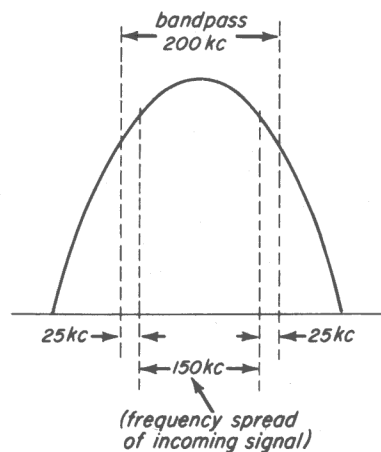


Fig. 38-4

oscillator. A special capacitor known as a *negative temperature coefficient* capacitor is connected across the oscillator tuned circuit. The capacitance of this type of unit varies with heat. It produces a frequency change opposite to that resulting from heat-caused changes in the oscillator tube-socket, tube, and tuned-circuit components. The effects of drift are thus compensated for.

When a variable capacitor is used for tuning, the plates may be spaced widely; the capacitance variation resulting from a small heat-produced change in plate spacing is smaller when the plate spacing is large. Permeability-tuned coils are used more often than variable capacitors to tune the oscillator. Heat-produced changes in a coil have a smaller effect on frequency than heat-caused expansion of the plates of a variable capacitor.

In order to minimize drift, the oscillator may be operated to make use of a harmonic frequency rather than the fundamental. This technique is useful when a variable capacitor is used to tune the oscillator. The oscillator operates at a submultiple of the desired frequency ( $1/4$ ,  $1/2$ , etc. of the desired frequency). If the desired oscillator frequency is 110.7 mc when a 100 mc r-f signal is coming in, the oscillator may be operated at, for example, 55.35 mc; the second harmonic of the oscillator will be the desired 110.7 mc signal. The advantage of operating the oscillator at a lower frequency is that a larger variable capacitor may be used to tune to the lower frequency at which the oscillator works. Use of a

larger variable capacitor makes heat-caused changes a smaller proportion of the total variable capacitance (as well as interelectrode capacitance).

**Microphonics.** Tube electrodes or components in the circuit vibrate at an audio frequency. The vibrations are usually produced by sound waves coming from the loudspeaker. This type of vibration of tube electrodes or tuned circuit components changes the capacitance or inductance of the tuned circuit at a rapid (audio-frequency) rate. Therefore, the oscillator frequency changes rapidly as well. The result is that the desired oscillator signal is frequency-modulated. The receiver detector responds to this frequency modulation, and microphonic noises are heard. To avoid or minimize microphonics, the speaker is located at a part of the receiver widely separated from the oscillator tube and oscillator-tuned circuit components. Shock-mounting of the oscillator tube socket is sometimes used to minimize tube-caused microphonics. The slugs of permeability-tuned coils are fitted into the coils in such a way that their vibration is restricted to a minimum.

A simplified schematic diagram of an oscillator circuit frequently used on the FM band is illustrated in Fig. 38-5. The oscillator is a Colpitts type. Feedback takes place through the tube interelectrode capacitances.

Interelectrode capacitance exists between heater and cathode of the oscillator tube. This interelectrode capacitance forms part of a circuit that shunts the oscillator tuned circuit (Fig. 38-6a, b). When the interelectrode capacitance changes due to

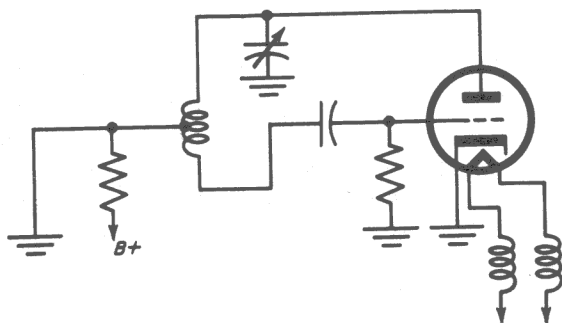
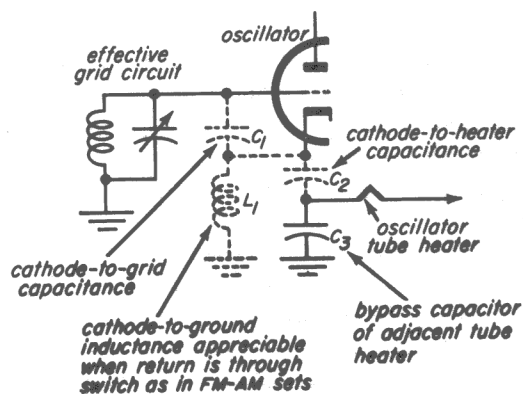
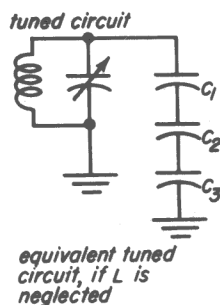


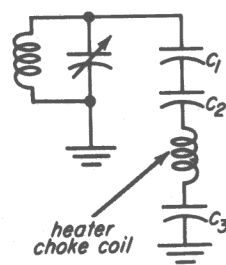
Fig. 38-5



(a)



(b)



(c)

Fig. 38-6

microphonics or during the warming up of the receivers, the cathode-to-heater (as well as cathode-to-grid) capacitance is varied, causing changes in the net capacitance in shunt with the tuned circuit. Oscillator frequency drift is promoted. The addition of r-f choke coils in series with the heater introduces a high impedance into the circuit that shunts the oscillator tuned circuit (Fig. 38-6c). The shunting effect of this circuit is consequently reduced. Frequency drift during the set's warm-up period is made smaller, and the effects of oscillator microphonics are minimized as well.

Microphonics produce symptoms largely by varying the cathode-to-grid capacitance. The cathode-to-grid capacitance has an undesired return to ground through the cathode-to-heater capacitance (Fig. 38-6a). Inserting choke coils in series with this return increases the impedance of the circuit. Its shunting effect on the oscillator tuned circuit is reduced, and microphonic-induced changes in the impedance of the shunt circuit have less effect on the frequency of the tuned circuit.

**Mixers and Converters.** A converter, you will remember, is a tube that functions as a combined oscillator and mixer. The oscillator and r-f signals are electron-coupled within the tube to form the intermediate-frequency signal. In AM receivers, converters are commonly used to mix the oscillator and r-f signals. At FM frequencies, however, converters are not as satisfactory as separate mixer and oscillator tubes. A dual-purpose tube often serves as mixer and oscillator. The two tube sections are equivalent to two separate tubes, even though they are contained in the same envelope. A representative mixer circuit is shown in Fig. 38-7. It is very similar to the mixer used in an AM receiver (in cases when the receiver does not employ a converter). Injection of the oscillator signal into the mixer is achieved capacitively (by feeding the oscillator signal from the oscillator tank circuit to the grid of the mixer through a capacitor), or inductively (magnetic coupling of the mixer and oscillator tuned circuit coils). Coupling is often attained by simply positioning the mixer and oscillator coils close to each other on the chassis.

**Front-End Tuning Methods.** Many different systems of tuning have been used in the front end of the FM receiver. Variable inductance and variable capacitance tuning are used. One variable inductance system used is known as *permeability tuning*. It is used more often in FM sets than variable capacitance tuning. Tuning capacitors are more apt to introduce microphonics than coils are, since the plates of the capacitors vibrate readily. Also, heat-caused variations in the capacitance of a variable capacitor tend to change the oscillator frequency more than heat-caused changes in a variable coil. Furthermore, space is saved by the elimination of a large tuning capacitor, permitting

manufacturing economies; other economies result because variable coils cost less than the variable ganged capacitor they replace.

## 38-2. AUTOMATIC FREQUENCY CONTROL

Automatic frequency control (called AFC for short) is the name given to a system of keeping an oscillator on frequency, in spite of the oscillator's tendency to drift. Automatic frequency control systems are used in AM communication receivers and television receivers, as well as in FM sets. In the FM receiver, AFC is used not only to compensate for oscillator drift, but also to simplify station tuning.

Correct tuning of an FM receiver using a limiter-discriminator combination is not easy, since neither of the two closely-adjacent points at which maximum volume occurs is the same as the point at which distortion is absent. Since the set user is accustomed to tuning for maximum volume in broadcast AM sets, he finds it difficult to readjust his habits and tune for no distortion instead. In the case of an FM receiver using a ratio detector, tuning is less difficult, since the set user simultaneously tunes for both maximum volume and no distortion. It still is somewhat difficult to get the exact point on the dial where the station is received with no distortion, since very close to this point on the dial are settings at which distortion is marked. When an AFC system is used in the receiver, the receiver automatically adjusts itself for optimum reception, regardless of whether the desired station has been correctly tuned in or not.

Appreciable oscillator drift can occur in an FM receiver for twenty minutes after the set has been turned on. AFC, by reducing oscillator drift to a negligible amount, makes it unnecessary for the set user to re-tune his set during the period while it is warming up. The anti-drift action of an AFC system is more effective than that of a negative temperature coefficient capacitor.

The two essential stages in an AFC system are a frequency discriminator and a reactance tube. In FM receivers, the FM detector generally serves as the AFC dis-

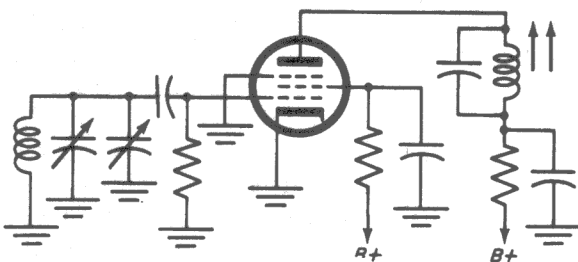


Fig. 38-7

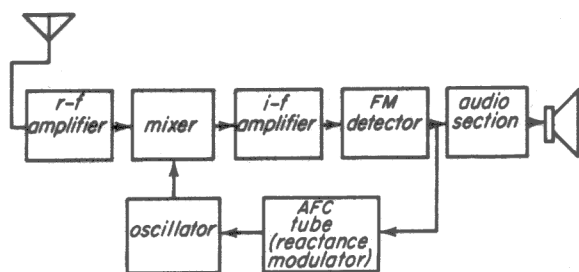


Fig. 38-8

criminator. A block diagram of a receiver using an AFC system, is shown in Fig. 38-8. When the oscillator is on frequency, the i-f carrier arrives at the center of the S curve of the FM discriminator. The d-c voltage output of the discriminator is zero when the carrier is coming in. The d-c voltage output of the discriminator at frequencies other than the carrier varies around this zero level (Fig. 38-9). When the oscillator frequency rises or falls (due to drift), the i-f carrier (without modulation) no longer arrives at the center of the S curve. There will be a d-c output from the discriminator even though the input is the unmodulated carrier. Frequencies above and below the carrier will produce audio voltages that rise above or fall below this d-c reference voltage.

The d-c voltage is positive when the carrier frequency moves in one direction; the d-c voltage is negative when the carrier fre-

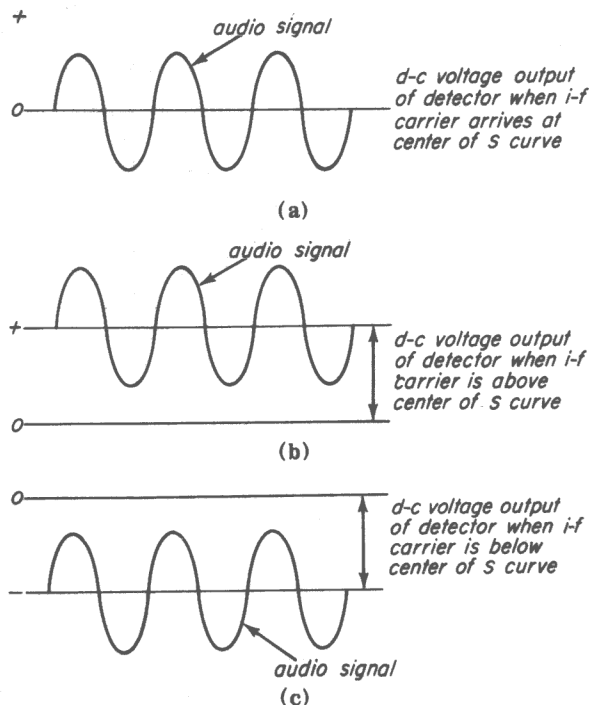


Fig. 38-9

quency moves in the opposite direction. This d-c voltage acts as a correction voltage. It is fed back to the grid of the reactance tube, where it acts as a bias voltage. The reactance tube is connected in parallel with the oscillator tuned circuit, and acts like a coil or capacitor in shunt with the tuned circuit. Changes in the bias of the reactance tube cause the reactance it presents to the oscillator tuned circuit to change; the oscillator frequency is changed accordingly, in a direction opposite to the original increase or decrease in frequency. The amount of frequency change produced by the correction voltage is equal to the original frequency change.

For instance, when the oscillator frequency rises by 200 cps, the correction voltages produce a change in the reactance of the reactance tube that brings the oscillator frequency down 200 cps. The reverse of this action occurs when the oscillator goes down in frequency. The frequency correction occurs almost instantaneously. The net result is that the oscillator stays on frequency.

A simplified reactance tube circuit is illustrated in Fig. 38-10a. One-half of a 12AT7 serves as the reactance tube; the other half of the tube acts as the oscillator.

In the reactance tube circuit, the plate current leads the plate voltage. The reactance tube presents a capacitive reactance to the oscillator tuned circuit.

Oscillator grid-to-ground signal voltage divides across  $C_1$ ,  $C_2$ ,  $R_1$ , and  $R_2$  (Fig. 38-10a). Since the capacitive reactance offered by capacitors  $C_1$  and  $C_2$  to the oscillator signal is relatively large, compared with the resistances of  $R_1$  and  $R_2$ ,  $I_g$ , the current flowing through  $C_1$ ,  $C_2$ ,  $R_1$ , and  $R_2$  will be capacitive.  $I_g$  will thus lead  $E_o$ , the signal voltage across the oscillator tuned circuit (Fig. 38-10b).  $I_g$  will also lead  $E_p$ , the plate-to-ground signal voltage of the reactance tube. ( $E_p$  is equal to the signal voltage across the oscillator tank circuit minus the signal voltage drop across  $C_1$ ).  $E_p$  is impressed across  $C_2$ ,  $R_1$ , and  $R_2$ , and since the reactance of  $C_2$  is much larger than the combined resistance of  $R_1$  and  $R_2$ , the current through these components will be

capacitive; which means that  $I_g$ , the current through  $C_2$ ,  $R_1$  and  $R_2$ , will lead  $E_p$ , the voltage applied across these components (Fig. 38-10c).

The signal voltage across  $R_1$  and  $R_2$  ( $E_g$ ) is in phase with the current flowing through  $R_1$  ( $I_g$ ), since the current through a resistive network is always in phase with the voltage across the network. These phase relations are indicated in Fig. 38-10d.

Since  $I_g$  leads  $E_p$ , and  $E_g$  is in phase with  $I_g$ ,  $E_g$  also leads  $E_p$ .  $E_g$ , the grid signal voltage, causes a plate signal current ( $I_p$ ) to flow in the reactance tube. The plate signal current is in phase with the grid signal voltage. Since  $I_p$  is in phase with  $E_g$ , and  $E_g$  leads  $E_p$ ,  $I_p$  also leads  $E_p$  (Fig. 38-10e). Therefore the reactance tube plate to ground circuit is one in which current leads voltage; that is, it is a capacitive circuit, and thus acts like a capacitor in parallel with the oscillator tuned circuit.

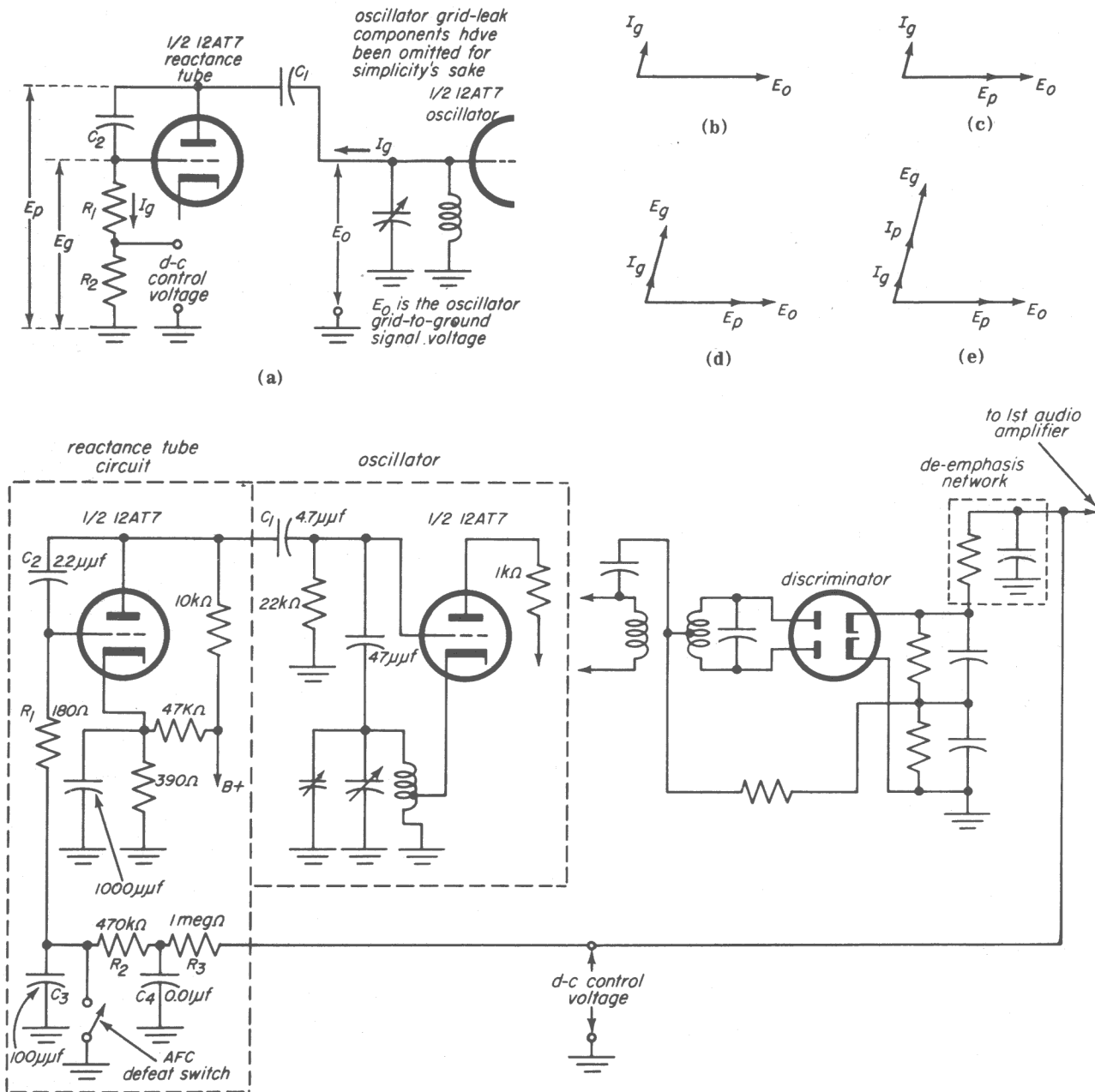


Fig. 38-10



When the oscillator is on frequency, the capacitive reactance presented by the reactance tube to the oscillator tuned circuit remains constant. This is so because no correction bias voltage occurs when the oscillator is on frequency. The reactance is equal to the rms value of the plate signal voltage, divided by the rms value of the plate signal current. These quantities do not change as long as the oscillator frequency remains correct. When the oscillator goes off frequency, the d-c control voltage fed back from the FM detector to the grid circuit of the reactance tube changes the bias of the reactance tube; this in turn changes the tube's plate current. The capacitive reactance of the tube alters, and the effective capacitance present across the oscillator tuned circuit is changed.

A representative AFC circuit is shown in Fig. 38-10f. You already are familiar with many of the components. We will discuss some that are unfamiliar.

$R_3$  and  $C_4$  form a filter that removes audio variations from the voltage fed back from the FM detector to the grid of the reactance tube. These a-c variations are not desired; only a pure d-c voltage is wanted. If audio signal were permitted to reach the reactance tube grid, the grid voltage would vary at an audio rate and cause the oscillator to undergo undesired changes in frequency.  $R_1$  forms part of the feed-back circuit existing between plate and grid of the reactance tube. It is equivalent to  $R_1$  in Fig. 38-10a.  $C_2$  corresponds to  $C_2$  of Fig. 38-10a. (In some AFC circuits,  $C_2$  is not used. The interelectrode capacitance between plate and grid of the reactance tube feeds back signal from plate to grid.) The ohmic value of  $R_1$  is very low compared with the reactance of  $C_2$ , so that the plate-to-ground circuit of the reactance tube will offer a predominantly capacitive reactance to the feedback current.  $C_3$  provides an a-c return to ground for the grid circuit of the reactance tube. It completes the feedback circuit for a-c voltage at the oscillator frequency. Since one side of the oscillator tank circuit connects to ground, one side of the grid circuit to which the oscillator tank voltage is applied (through several capacitors) must also be grounded.

The grid is returned to ground through  $C_3$  so that the feedback voltage applied from the detector to the reactance tube grid will not be shorted out before it reaches the grid. If a resistor were used in place of  $C_3$  to prevent such a short-circuit, an undesired division of voltage would take place across  $R_3$  and  $R_2$  on the one hand, and the resistor used in place of  $C_3$  on the other, and the correction voltage would be undesirably reduced. Because the capacitance of  $C_3$  is so large, compared with the capacitances of  $C_2$  and  $C_1$ , and its reactance is therefore so comparatively small,  $C_3$  introduces a negligible amount of phase shift in  $I_g$ , the signal current flowing through the reactance modulator grid circuit. Therefore, the  $E_p/I_p$  phase relation needed for proper operation of the reactance tube is undisturbed.

Automatic-frequency-control action is not desirable, during the tuning-in of a weak station whose frequency is very close to that of a strong station. The AFC system would act to change the frequency of the oscillator to the point where optimum tuning of the strong station takes place and the weaker station would be passed over. In order to avoid this the AFC defeat switch (Fig. 38-10f) can be used to short out the AFC control voltage. When the weak station has been correctly tuned in, the AFC switch can be opened, restoring AFC operation. The AFC will hold to the weak station after the weak station is tuned in.

### 38.3. AUDIO STAGES

FM stations can transmit frequencies representing audio signals ranging from 30 to 20,000 cps. In practice, a range of 30 to 15,000 cps audio is commonly transmitted. Higher-fidelity reception may be obtained from FM than from AM sets, not because of the intrinsic superiority of the FM receiver, but simply because the FM standards of transmission permits the full range of audio frequencies to be transmitted whereas the AM system does not. In order to reproduce this wide range of frequencies, the audio stages of the FM receiver would require a bandpass extending from 30 to 20,000 cps. Most FM receivers do not have audio bandpass extending to 20,000 cps.

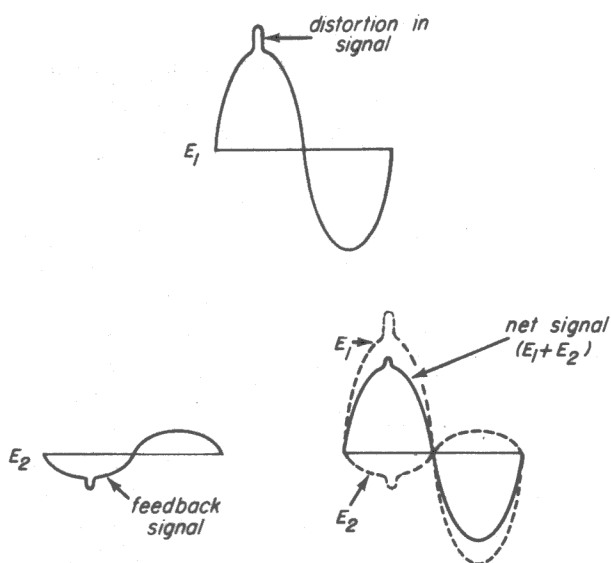


Fig. 38-11

However, a good FM receiver has audio stages capable of passing a very wide range of audio frequencies — much wider than the range of frequencies passed by the audio stages of a conventional AM receiver.

In practice the chief differences between the audio stages of FM receivers and audio stages in AM receivers are the use of negative feedback and a superior system of tone control in FM receivers. Negative feedback, in which a fraction of the output of an audio amplifier is fed back to the input so as to buck the input voltage minimizes certain types of distortion (Fig. 38-11). Negative feedback reduces gain.

A representative system of negative feedback is shown in Fig. 38-12. An out-of-phase signal from the voice coil circuit is fed back to the input of the power amplifier in this system. Although feedback over one stage is shown, feedback over several stages may be used. FM receivers that have wide-range audio amplifiers generally use a superior system of tone control. Actual bass and treble boost controls (instead of the simpler tone controls used in many AM receivers) are frequently used in the audio stages of FM sets. Speakers superior to those used in AM sets are generally used in comparable quality FM sets. A woofer and tweeter may be incorporated to provide proper response at low and high audio frequencies.

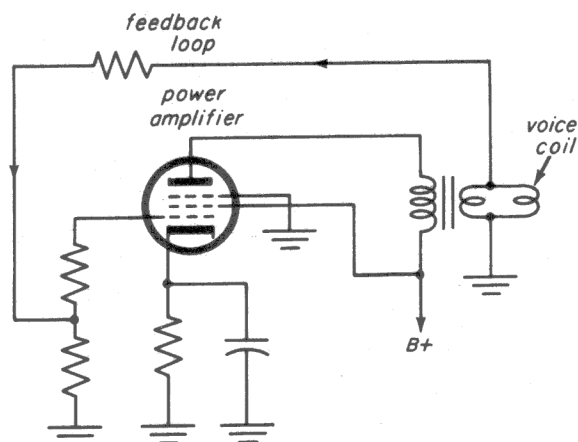


Fig. 38-12

### 38-4. FM-AM RECEIVER ANALYZED

Now that we have completed our discussion of individual FM receiver circuits, we can analyze a complete receiver schematic diagram. The schematic diagram of an FM-AM receiver is shown in Figs. 38-13. (Straight FM sets are not common, FM-AM receivers are much more usual.) Fig. 38-13a shows the circuit with the FM-AM-PHONO switch set to bring in FM reception; Fig. 38-13b shows the circuit on AM switch setting. Refer to Fig. 38-13a when components in FM circuits are discussed; refer to Fig. 38-13b when components in AM circuits are discussed. In the case of audio and power supply circuit components, either figure can be used.

The power supply uses a selenium rectifier. Filament chokes and filament bypass capacitors are used to prevent undesired coupling of r-f signals from one stage to another via the cathode-to-heater capacitance of the tubes. (R-F signals developed in the cathode circuit of a tube can be coupled to the heater of the same tube via the heater-to-cathode capacitance. From the heater of the tube, the r-f signal can be passed to the heater of another tube; from the heater of this second tube, the r-f signal can get into the cathode circuit of the tube via the heater-to-cathode capacitance. Oscillation or regeneration can result from such undesired coupling; the filament chokes and filament bypass capacitors prevent this condition.) The pilot lights are fed from an autotransformer ( $T_8$ ) that steps down the line voltage to 6.3 volts. Two pilot lights



**Fig. 38-13 (a)**



**Fig. 38-13 (b)**

are needed because the receiver has two separate dials; each pilot light illuminates one dial. A section of the FM-AM switch (designated S1-B FRONT) connects the proper pilot light to the autotransformer tap on each service.

The power amplifier uses an output transformer with a tapped primary. The section of the winding *below* the tap feeds a hum voltage into the secondary that is opposite in polarity to the hum voltage fed to the secondary from the winding *above* the tap. Hum is minimized as a result. The fact that the plate of the power amplifier feeds through the output transformer to a point in the power supply where substantial hum is present makes this hum-bucking arrangement necessary. The plate is supplied from this point (rather than from a point where a better filtered d-c voltage exists) to provide a higher d-c plate voltage for the power amplifier.  $R_{13}$ , a 1.2 k-ohm resistor, serves as a filter choke; the substantially pure d-c voltage present at the output side of  $R_{13}$  (the side that connects to C33A) is used as a source of B+ for other tubes.

The potentiometer in the plate circuit of the 12AV6 (the detector-AVC-audio amplifier tube) has a dual tone-control action. With the variable arm of the potentiometer at the top of the control (closest to the bottom of  $C_{12}$ ) maximum shunting of high frequencies occurs in the plate circuit, producing a tonal effect of maximum bass. Maximum shunting of high frequencies also occurs in the grid circuit (at the low-volume settings) because of the tone-compensated volume control used in this circuit. When the variable arm of the volume control is at or close to the tap point of the volume control,  $R_6$  and  $C_{11}$  in series have a much greater shunting effect on high than on low frequencies. With the variable arm of the tone control at the bottom of the control (nearest the top of  $C_{11}$ ), the shunting of high-frequency audio signals at the plate of the 12AV6 is minimum. Since  $C_{11}$  is short-circuited at this setting, no discrimination against high frequencies occurs in the grid circuit;  $R_6$  alone, not  $R_6$  in series with  $C_{11}$ , now shunts the lower section of the volume control.

The discriminator circuit is fairly conventional. A single capacitor ( $C_{26}$ ) is used as an i-f bypass across broad resistors  $R_{24}$  and  $R_{25}$ , instead of two capacitors (one across each resistor).  $R_{26}$  and  $C_{27}$  make up de-emphasis circuit. The audio output of the discriminator is fed through d-c blocking capacitor  $C_{28}$ , through the AM-FM-PHONO switch, to the volume control (when the switch is at FM setting). The plate of the second i-f amplifier and the grid of the third i-f amplifier (the limiter stage) use a common tuned circuit and capacitive coupling in place of double tuned transformer coupling.  $T_2$  and  $T_4$  are the AM i-f transformers. On AM operation, the AM detector circuit consists of the diode plate of  $V_7$ , the secondary of  $T_4$ , through the FM-AM-PHONO switch, to the volume control which serves as the AM detector load.

On AM operation, the top of the volume control feeds through the FM-AM-PHONO switch to the AVC resistor ( $R_5$ ) and the AVC capacitor  $C_4$ . AVC voltage is applied to the grid of  $V_3$ , the AM-FM i-f amplifier, and  $V_1$ , the r-f amplifier on AM operation. The second i-f amplifier ( $V_4$ , Fig. 38-13a), the limiter ( $V_5$ ) and the discriminator ( $V_6$ ) are used only on FM operation; the other receiver tubes are used on both FM and AM. A built-in loop antenna is switched to the input of the r-f amplifier on AM operation. On FM, the power line acts as the antenna. The line is capacitively coupled to the FM antenna input by placement of a conductor near the line. The antenna input consists of  $C_2$  (a capacitor) and  $L_5$  (a coil).

The grid circuit of the r-f amplifier is untuned on the FM switch setting. There is adequate selectivity in the FM receiver without a tuned r-f amplifier grid circuit.  $L_2$  and the capacitors associated with it tune the mixer grid circuit on FM setting; they also help tune the plate of the r-f amplifier at this setting.  $L_4$  and the capacitors associated with it tune the mixer grid circuit on AM setting; they also help tune the r-f amplifier plate at this setting.

The mixer grid circuit on AM setting connects through  $C_7$  and the S1A REAR section of the switch not to the top of  $L_4$ , which is the conventional connection, but to the

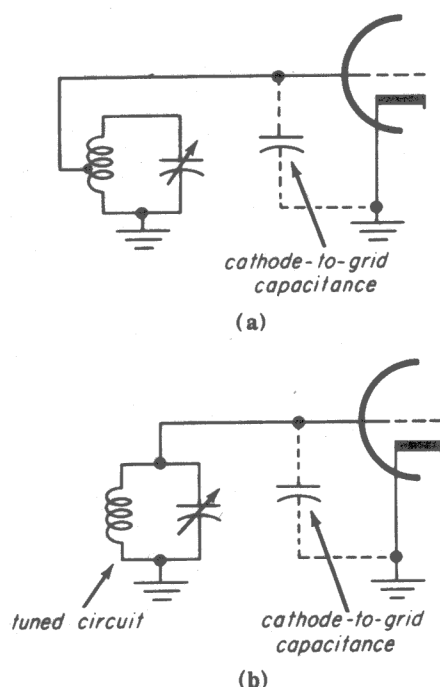


Fig. 38-14

tap on  $L_4$ . This type of connection minimizes possible detuning of the mixer grid on AM operation and loss of selectivity. (Selectivity is a much more critical problem on the AM band than on the FM band, due to closer channel spacing on AM and the possibility of interference at a much smaller level of interfering signal.) Detuning is possible because of variations in the input capacitance of the mixer tube with changes in the level of the incoming signal. By placing the mixer input capacitance (which consists largely of the cathode-to-grid capacitance) across a portion of the mixer grid tuned circuit (Fig. 38-14a), rather than across the whole tuned circuit (Fig. 38-14b), the effects of variations in the input capacitance are reduced.

Different types of oscillators are used for AM and FM operation.  $L_6$  and its associated capacitors form the tuned circuit of the cathode coupled tickler feedback oscillator used on AM operation. On FM operation,  $L_8$  and its associated capacitors form the tuned circuit of a Colpitts oscillator. Use of a Colpitts oscillator is desirable in an FM receiver; the Colpitts is stable at FM frequencies.

On AM operation, injection of the oscillator signal into the mixer is achieved by

means of the oscillator tickler coil  $L_7$ , which serves as a common cathode impedance for both the mixer and oscillator sections of the 19X8. The r-f current of the incoming signal flows through  $L_7$  as a result of the application of the r-f signal to the grid of the mixer; oscillator signal current also flows through  $L_7$ . To stop the AM oscillator on FM operation,  $L_7$  is shorted out through the FM-AM-PHONO switch, and injection of oscillator signal into the mixer takes place through inductive coupling of the mixer and oscillator coils. Decoupling circuits made of a resistor and a capacitor ( $C_5$  and  $R_1$  in the plate circuit of the r-f amplifier for example) are used in the r-f/i-f stages to keep radio-frequency signals out of the power supply. If these signals were permitted to get into the power supply, they would develop r-f signal voltages across the impedance of the output electrolytic filter capacitor. (The impedance of an electrolytic capacitor at radio frequencies is appreciable.) B+ voltage fed to one stage might contain r-f signal from another stage; the resultant feedback would produce regeneration, oscillation, or degeneration. Decoupling circuits prevent such undesired circuit action. Grid circuit decoupling is also used, to prevent coupling of stages through the AVC system on AM operation.  $R_{15}$  and  $C_{39}$ , for instance, form a decoupling network in the grid circuit of  $V_3$ .

### 38-5. MULTIPATH DISTORTION

When the r-f signal from an FM transmitter arrives at a receiver via one or more reflected paths in addition to the direct path (multipath reception) — the reflected signals can interfere with the direct signal because the reflected signals travel a longer distance and take a longer time to arrive at the receiver than does the direct signal. Because the reflected signals are delayed in time, they can be out of phase with the direct signal and can partially cancel the direct signal. This kind of interference can happen to AM signals as well as to FM signals. In an AM receiver, this interference due to multipath reception causes either simple fading of the reproduced sound or else causes selective fading of some of the reproduced sound frequencies and alters the

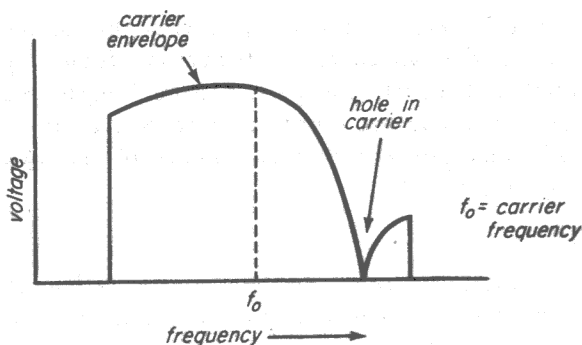


Fig. 38-15

tone of the sound. In an FM receiver, multipath reception causes a severe distortion of the reproduced sound called *multipath distortion*.

Figure 38-15 will help you to understand why reception of a multipath signal that causes only selective fading of an AM signal can cause distortion of an FM signal. Remember that both AM and FM r-f signals carrying sound to the receiver are made up of a signal at carrier frequency and frequencies to both sides of the carrier. In AM transmissions, the side frequencies are sidebands representing the various tone frequencies of the sound. In FM, the side frequencies are not simply sidebands. The frequencies to the sides of an FM carrier represent the frequencies through which the signal is continuously deviating (at the rate of the tone frequencies of the sound). Each individual side frequency represents an instantaneous amplitude of the sound signal. A loud sound is represented by side frequencies that deviate far from the carrier frequency; a weak sound is represented by side frequencies that deviate not-so-far from the carrier.

Figure 38-15 shows the curve of the envelope of a carrier and its side frequencies. As shown by the dip of the envelope enclosing r-f to the right of the carrier, multipath interference causes cancellation of some of the side frequencies. In AM, this causes selective fading and alteration of the tone of the sound. In FM, it causes a distortion of the amplitude characteristics of the sound signal; it causes amplitude distortion like that produced in a defective audio amplifier. The audible effect of all kinds of amplitude distortion of the sound

signal is a garbling of the sound. Like the amplitude distortion caused by a defective audio amplifier, multipath distortion may be worst on loud sounds. However, multipath distortion can be distinguished from amplitude distortion produced by a defect within the receiver as follows:

1. Multipath distortion does *not* usually show up on base tones (below about 300 cps). Amplitude distortion produced within a receiver shows up *mostly* on base tones.

2. Multipath distortion does not usually show up on all stations that can be received in a particular locality (unless only one of or two stations can be received); internal amplitude distortion does show up on all stations.

3. Moving the FM receiver antenna changes the quality of multipath distortion, but has no effect upon internal amplitude distortion.

In localities where many FM broadcast stations operate, it is usual to receive multipath distortion on one or two stations. Multipath distortion is one of the more serious disadvantages of FM broadcasting, just as static is one of the more serious disadvantages of AM broadcasting. It is more likely that multipath distortion will be picked up on a built-in receiver antenna or a power line receiver antenna than on an outdoor, dipole FM receiver antenna. This is because the dipole intercepts more signal; it is a better signal interceptor and it is mounted high (on the roof). Because the antenna is in an unobstructed outdoor location and has a directional receptivity response characteristic, it is less apt to intercept reflected signal.

In order to eliminate multipath distortion, you should alter the receiver antenna as follows:

1. Move the antenna to alter the relative lengths of the direct and reflected incoming signal paths.
2. Try to pick up more signal from the direct path.

FM broadcast antennas are directional and can be oriented to intercept more direct signal than reflected signal. When the direct is much stronger than the reflected signal, the reflected signal cannot cause sufficient cancellation to distort the sound. Nevertheless, changing the antenna location to alter the lengths of the signal paths is the most effective remedy for multipath distortion. It is enough to move the antenna a few feet. A full wavelength at the FM broadcast frequencies is roughly 6 feet. At most, it is necessary to alter the relative phase of direct and reflected signal by  $180^\circ$ . In order for this to be accomplished, the path length of either signal has to be altered by only

about 3 feet. Moreover, by moving the antenna in the appropriate direction (found by trial and error), one path can be lengthened  $1\frac{1}{2}$  feet while the other is shortened  $1\frac{1}{2}$  feet; this changes the relative phase of the two signals by  $180^\circ$ .

Briefly stated, the remedy for multipath distortion is to install an outdoor dipole antenna positioned and oriented by trial and error for minimum distortion. Of course, a position and orientation that minimize distortion on one station may introduce it on another station; thus all stations must be checked during the trial and error process.

